

FORM PTO-1390
(REV. 12-2001)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

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TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371

NOR-951A

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)

10/088464

INTERNATIONAL APPLICATION NO.
PCT/US00/25282INTERNATIONAL FILING DATE
September 15, 2000PRIORITY DATE CLAIMED
September 20, 1999

TITLE OF INVENTION

Apparatus And Method For Generating Ultraviolet Radiation

APPLICANT(S) FOR DO/EO/US

James W. Schmitkons and James M. Borsuk

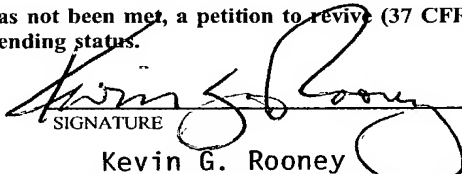
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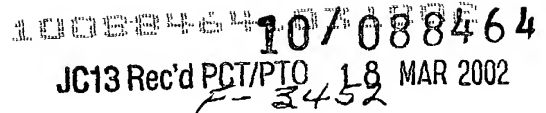
1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☐ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ has been communicated by the International Bureau.
 - c. ☒ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
 - a. ☐ is attached hereto.
 - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
 - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ have been communicated by the International Bureau.
 - c. ☐ have not been made, however, the time limit for making such amendments has NOT expired.
 - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). **(Executed)**
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98. **(9 References)**
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A **FIRST** preliminary amendment.
14. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information:

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U.S. APPLICATION NO. (known) 10/088464		INTERNATIONAL APPLICATION NO. PCT/US00/25282		ATTORNEY'S DOCKET NUMBER NOR-951A		
21. <input checked="" type="checkbox"/> The following fees are submitted: BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)): Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO. \$1040.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO \$890.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$740.00 International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) \$710.00 International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) \$100.00 ENTER APPROPRIATE BASIC FEE AMOUNT =				CALCULATIONS PTO USE ONLY		
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$		
CLAIMS		NUMBER FILED	NUMBER EXTRA	RATE	\$	
Total claims		29 - 20 =	9	x \$18.00	\$ 162.00	
Independent claims		4 - 3 =	1	x \$84.00	\$ 84.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)				+ \$280.00	\$	
TOTAL OF ABOVE CALCULATIONS =					\$ 956.00	
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.					\$	
SUBTOTAL =					\$ 956.00	
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).					\$	
TOTAL NATIONAL FEE =					\$ 956.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property +					\$ 40.00	
TOTAL FEES ENCLOSED =					\$ 996.00	
					Amount to be refunded:	\$
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a. <input checked="" type="checkbox"/> A check in the amount of \$ 996.00 to cover the above fees is enclosed.						
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NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.						
SEND ALL CORRESPONDENCE TO: Kevin G. Rooney, Esq. Wood, Herron & Evans, L.L.P. 2700 Carew Tower 441 Vine Street Cincinnati, OH 45202 (513) 241-2324						
					 SIGNATURE	
					Kevin G. Rooney	
					NAME	
					36,330	
					REGISTRATION NUMBER	



PROCESS FOR GENERATING ULTRAVIOLET RADIATION FROM A MICROWAVE -SOURCE AND DEVICE FOR IMPLEMENTING THIS PROCESS

whereby this field is produced from a suitable microwave source coupled to a cavity or chamber adapted for this purpose, inside which the tube is located.

But in order to obtain a homogeneous emission of ultraviolet rays over a sufficient dimension inside the tube, and in particular along the entire length of the tube, which may be as much as 20 cm or more, so that the light flux obtained hits the product to be treated along a uniform strip or region whose relative movement by moving the product creates a continuous and regular treatment over the entire surface of this latter, the electric field must be distributed in the tube by means of a traveling wave at constant amplitude, but with an intensity which is also sufficient to induce the required discharge and maintain it.

U.S. Patents No. 3,872,349 and No. 4,042,850 in the name of Fusions Systems Corporation illustrate embodiments of this type, with an electrodeless tube excited by hyperfrequency radiation, in particular between 1 and several tens of gigahertz, and preferably equal to 2,450 MHz, the standard frequency in industrial microwave applications.

These patents describe in detail the physical theory which makes possible the production of ultraviolet radiation under the effect of an electric field of constant amplitude, in which the electrons collide with the ions of the gas confined in the sealed tube, producing a suitable light emission by changing energy levels.

Nevertheless, an essential characteristic of the prior art thus represented consists in exclusively using a traveling wave through the tube, but carefully preventing any stationary wave which might result from a resonance phenomenon in the propagation of the electromagnetic wave coupled to the cavity containing this tube. In fact, in the case of such resonance with a suc-

cession of nodes and antinodes occurring along the length of the tube, with this latter positioned in the direction of the fundamental mode of the wave created, it is evident that the light energy of the ultraviolet radiation produced will mainly be emitted to the right of the areas where the electric field is maximum, thus at the antinodes, with first a decrease from these latter along the longitudinal dimension of the tube to a minimum corresponding to a node, then an increase to the next antinode, and so on. The ultraviolet radiation emitted will therefore be essentially variable along the tube length, and will not permit a homogeneous distribution over the sheet or other material to be treated, which is generally moving parallel to the tube.

To avoid such a resonance, the above-cited patents therefore specify traveling wave devices, where the hyperfrequency energy coming from appropriate emitters is coupled to the cavity and to the tube it contains by slots staggered axially and laterally, opposite to one another with respect to the direction of the discharge tube and the ends of the cavity containing it. In addition, two emitters are generally used, respectively coupled to two slots thus staggered, and their frequencies are themselves separated by a gap of about 15 MHz on either side of the average frequency of 2,450 MHz.

These known systems, widely sold today, have advantages over those using lamps with electrodes under voltage, thanks in particular to a rapid rise to temperature and to the option of almost instantaneous successive starting and extinguishing, which is particularly useful for treatments where the ultraviolet radiation must be very accurately controlled. Because of the absence of electrodes, the tube used is more luminous and can be more extensively utilized over its entire longitudinal dimension for the production of the radiation used. In addition, the simultaneous emission of infrared radiation is

reduced, thereby limiting the release of heat from the tube and noticeably increasing its useful life.

On the other hand, other drawbacks persist: in fact, these systems are limited in size and in power, since the energy supplied to the cavity and to the tube contained in it is distributed along the entire length of this tube by the traveling wave created, with definite losses overall. In addition, the coupling of the microwave energy to the tube is sometimes difficult to ensure so as to make it possible to keep a perfectly constant electric field amplitude over the entire length of the tube where the traveling wave propagates.

It is known, moreover, that in other known embodiments with a resonant structure, the propagation of an electromagnetic wave, in particular at 2,450 MHz, usually occurs in fundamental mode in a standard guide with a rectangular cross section where the short side is equal in this case to about 4.3 cm. If the electrodeless tube is placed in the axis of the guide and at its center, and if the structure is resonated, the succession of nodes and antinodes in the electric field distribution is therefore going to create, to the right of the antinodes, regions of maximum field where the emission of ultraviolet radiation will be the most intense. In these regions, the electric field component is directed in a diametral plane of the tube, perpendicular to the long sides of the guide and therefore parallel to its short sides. The result is that in this case, the ultraviolet radiation coming from the tube will be emitted over a length of only 4.3 cm, with, as described above, a succession of areas of emission and extinction along the length of the tube which are quite disadvantageous if the ultimate goal is to obtain a homogeneous distribution over an acceptable distance.

Finally, French Patent No. 82/04,398 of March 16, 1982, in the name of

the CNRS (National Center for Scientific Research) discloses a process and a device for the direct microwave treatment of sheet products, which consist in using microwave applicators in the form of elongated resonant cavities where electric field distribution is achieved with a succession of nodes and anti-nodes along the main axis of each applicator. These have a prismatic shape, in particular with a rectangular cross section, where the dimension of this cross section parallel to the electric field is adjusted to approach the TE₀₁₂ mode resonance conditions, and has for this purpose a dimension at least greater than double the other side of the same cross section.

According to the information of this French patent, we thus learn that compared to a standard guide with a rectangular cross section, where the side perpendicular to the direction of the electric field is close to 8.6 cm and the side which is parallel is 4.3. cm, we can give this latter dimension a much higher value, which may be between 8 and 10 cm, and preferably is 9.1 cm. It has since been found that this same dimension can be increased up to 20 or even 25 cm, without altering the resonance conditions in the guide for the mode in question.

The object of the present invention is a process and a device which, by implementing the above specifications, avoids the limitations of traveling wave systems of the type reviewed above, making it possible, for a given energy applied to the cavity containing the electrodeless tube, to supply a higher-powered ultraviolet radiation using stationary waves in a resonant structure in accordance with the instructions of the above-mentioned French patent, with adaptation of these latter to the new application more specifically intended.

Moreover, the invention aims to provide a system where the coupling of

the hyperfrequency field to the electrodeless tube is more efficient, while making use of a simpler production technique which requires only one means for tuning the resonance frequency in the cavity receiving the tube and produces overall a more reliable, less cumbersome, and above all less expensive device than with the prior solutions, in particular the traveling wave designs.

For this purpose, the process according to the invention, using an electrodeless tube placed in a cavity excited by at least one microwave generator and resonated at an appropriate mode, is characterized by the fact that it consists in orienting the polarized stationary electric field at constant amplitude parallel to the axis of the discharge tube, and in overdimensioning the cavity so that the tube has its longitudinal dimension along a resonance antinode of the mode excited in the cavity.

The invention consists, in other words, of a new application of the process known by the above-mentioned French patent, by adapting to it the known method consisting of an electrodeless tube containing a plasma and having a flow of polarized electrons act on it, defining the electric field component of a hyperfrequency radiation supplied by a microwave generator. The collisions on the ion atoms of the gas in the tube cause the emission of light radiation, in particular in the ultraviolet region. The specified application uses an overdimensioned resonance structure, so that the tube extends along a resonance antinode and is thus excited over its entire longitudinal dimension, permitting a significant increase in the overall energy yield of the structure.

The device for implementing the process is characterized by the fact that it consists of a resonant cavity, at least one microwave emitter feeding into this cavity, a means of coupling between the cavity and the emitter, a device

for adjusting the frequency tuning of the cavity, and an electrodeless tube containing a gas at a given pressure, placed in the cavity along the direction of the electric field component for the excited mode, whereby the cavity is overdimensioned so that said component has a resonance antinode along the length of the tube.

In a first variant of the device under consideration, the cavity is prismatic and has a rectangular cross section to allow excitation of the TE₀₁₂ mode of the hyperfrequency radiation, whereby the tube is placed along the zero-order direction of the mode.

In another variant, the cavity is cylindrical, with a partially elliptical cross section, whereby the tube is placed along one of the foci of the cavity. Preferably, this latter has a polished reflecting wall making it possible to focus the ultraviolet radiation emitted by the tube at the other focus of the cavity, excited on the TM₀₁₀ mode of the hyperfrequency radiation.

According to another particular characteristic of the invention, the cavity has an open side parallel to the tube and consisting of a fine mesh transparent to the ultraviolet radiation emitted by the tube and opaque to the hyperfrequency radiation.

Advantageously, the device has two microwave emitters of identical or very similar frequency, with the difference in frequencies being less than the passband of the resonant cavity, so that the effects of each emitter are additive.

Also preferably, the frequency of the microwave radiation is 2,450 MHz, whereby the tube mounted in the cavity has a length of at least 20 cm.

In still another variant, the microwave emitters can have a variable

power and excite the resonant cavity by means of an insulator which absorbs the wave reflected by the cavity while protecting the emitters. The wave reflected by the resonant cavity, in particular during transitory excitation conditions, is advantageously absorbed by a traditional water load.

Other characteristics of the process and the device according to the invention will become evident from the description which follows of two embodiment examples, given as a guideline and nonlimiting, with reference to the attached drawings, in which:

- Figure 1 is a schematic drawing of the device according to the invention; and
- Figures 2 and 3 are perspective views of two respective variants of the resonant cavity containing the electrodeless tube, for the emission of ultraviolet radiation.

In the diagram in Figure 1, 1 indicates a microwave generator of suitable power, but generally chosen as 1,200 W under nominal conditions. This generator is excited by a modulator 2 and delivers a hyperfrequency radiation into an adjusted guide 3 connected to an insulator 4, which is itself coupled by another guide 5 to a water load 6. The radiation usually has a frequency of 2,450 MHz.

The insulator is also connected by a third guide 7 to an appropriate coupling means (of the iris or half-wave antenna type) with a resonant cavity 8. Over most or all of it, this latter contains an electrodeless tube 9 containing a pressurized gas and such that the effect of the electric field E component 10 created in the cavity 8 by the radiation from the emitter produces an emission of ultraviolet radiation, indicated in the figure by the wavy arrows, extending in a plane passing through the axis of the tube and perpendicular to

the short side of the cavity. A harmonizer 11 makes it possible to adjust the frequency in the cavity 8 if necessary, and in particular to bring it to the resonance according to an appropriate mode, so that an electric field antinode develops along the longitudinal dimension of the tube 9 which is equal to 20 or even 25 cm, thus permitting homogeneous and regularly distributed emission of the ultraviolet radiation.

In the example illustrated in Figure 2, the resonant cavity 8 containing the tube 9 has a prismatic form with a rectangular cross section; its long side a corresponds to a zero-order TE₀₁₂ mode, parallel to the component 10 of the electric field E , and the sides b and c of the cross section correspond to orders 1 and 2 of the above mode. The guide 7 through which the microwave radiation is fed to the cavity 8 has an appropriate coupling slot 12. In addition, opposite the guide 7 the cavity 8 has an open face 13, in the plane of which there is a fine mesh 14 which allows the microwave radiation from the tube 9 to pass through along the arrows 15 with little alteration but prevents the escape of the hyperfrequency radiation from the cavity, where it thus remains confined.

The ultraviolet radiation thus produced homogeneously over the entire length of the tube 9 along the length of the tube 9 delimits a continuous strip 16 of the same size on a material 17 to be treated, which can be moved along the direction of the arrow 18 by any appropriate means (not shown) to allow a complete treatment of the entire surface, for example to dry a layer of ink or varnish coating it.

Figure 3 illustrates another variant of the cavity 8, in which it is in the form of a chamber with a partially elliptical cross section. The inside wall 19 of the cavity 8 is preferably made of a material which is reflecting

for the ultraviolet radiation produced. Here the tube 9 is placed parallel to an axis of the chamber at one of the foci of the corresponding ellipse. The strip 16 formed on the sheet of material 17 in the region where the ultraviolet radiation is concentrated is positioned at the second focus of the same ellipse. In this variant, the opening 13 is covered by the mesh 14 to allow confinement of the hyperfrequency radiation but escape of the ultraviolet rays, as in the preceding example.

Thus a source of radiation is obtained which is perfectly suited to the treatments under consideration. It is simple in design and noticeably lower in cost than the solutions known in the art, requiring a greatly reduced microwave energy for a given supplied power. Nevertheless, it must be understood that the invention is not limited to the examples described, but encompasses all the variants within the scope of the man of the art.

the TM010 mode of the hyperfrequency radiation.

6. Device according to any of Claims 2-5, characterized in that the cavity (8) has an open side (13) parallel to the tube (9) and consisting of a fine mesh (14) transparent to the ultraviolet radiation emitted by the tube and opaque to the hyperfrequency radiation.

7. Device according to Claim 2, characterized in that it has two microwave emitters of identical or very similar frequency, whereby the frequency difference is less than the passband of the resonant cavity (8), so that the effects of each emitter are additive.

8. Device according to any of Claims 2-7, characterized in that the frequency of the microwave radiation is 2,450 MHz, whereby the tube mounted in the cavity has a length of at least 20 cm.

9. Device according to any of Claims 2-8, characterized in that the microwave emitter or emitters have variable power and excite the resonant cavity (8) by means of an insulator (2) which absorbs the wave reflected by the cavity and protects the emitter or emitters.

10. Device according to Claim 9, characterized in that the wave reflected by the resonant cavity (8) during the transitory excitation conditions is absorbed by a water load (6).

11. Application of the process according to Claim 1 to the treatment of materials in motion relative to the ultraviolet radiation produced.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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60/155,028 20 September 1999 (20.09.1999) **US**

(71) Applicant (for all designated States except US): **NORD-SON CORPORATION** [US/US]; 28601 Clemens Road, Westlake, OH 44145 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **SCHMITKONS,**

James, W. [US/US]; 43530 Middle Ridge Road, Lorain, OH 44053 (US). **BORSUK, James, M.** [US/US]; 30848 Lytham Circle, Westlake, OH 44145 (US).

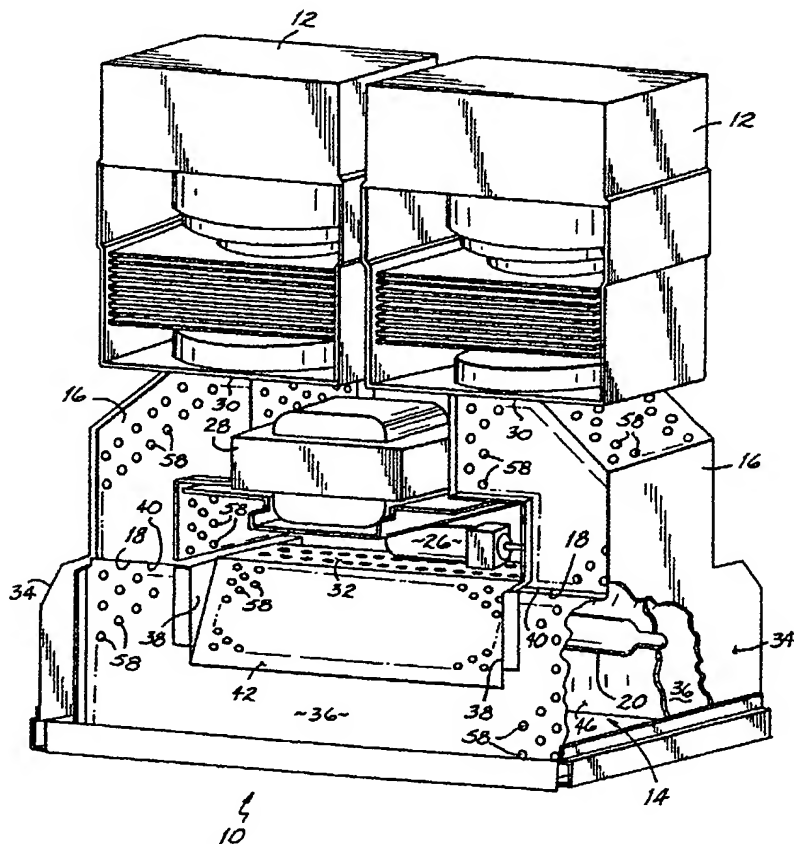
(74) Agents: **BRINKMAN, David, W.** et al.; Wood, Herron & Evans, L.L.P., 2700 Carew Tower, Cincinnati, OH 45202 (US).

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[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR GENERATING ULTRAVIOLET RADIATION



(57) Abstract: An apparatus (10) for generating ultraviolet radiation includes a pair of magnetrons (12) coupled to a longitudinally extending microwave chamber (14) for generating standing microwave energy waves within the chamber (14). Microwave energy from the magnetrons (12) is directly coupled to the microwave chamber (14) without the use of coupling slots, antennas or other coupling structures. A longitudinally extending electrodeless plasma bulb (20) is mounted within the microwave chamber (14) and is operable to emit ultraviolet radiation (24) in response to excitation by the microwave energy generated by the pair of magnetrons (12). The microwave chamber (14) includes a pair of longitudinally extending tuning walls (42) positioned on opposite sides of the plasma lamp bulb (20) and capable of overlapping the standing microwave energy waves generally along the longitudinal length of the plasma bulb (20).

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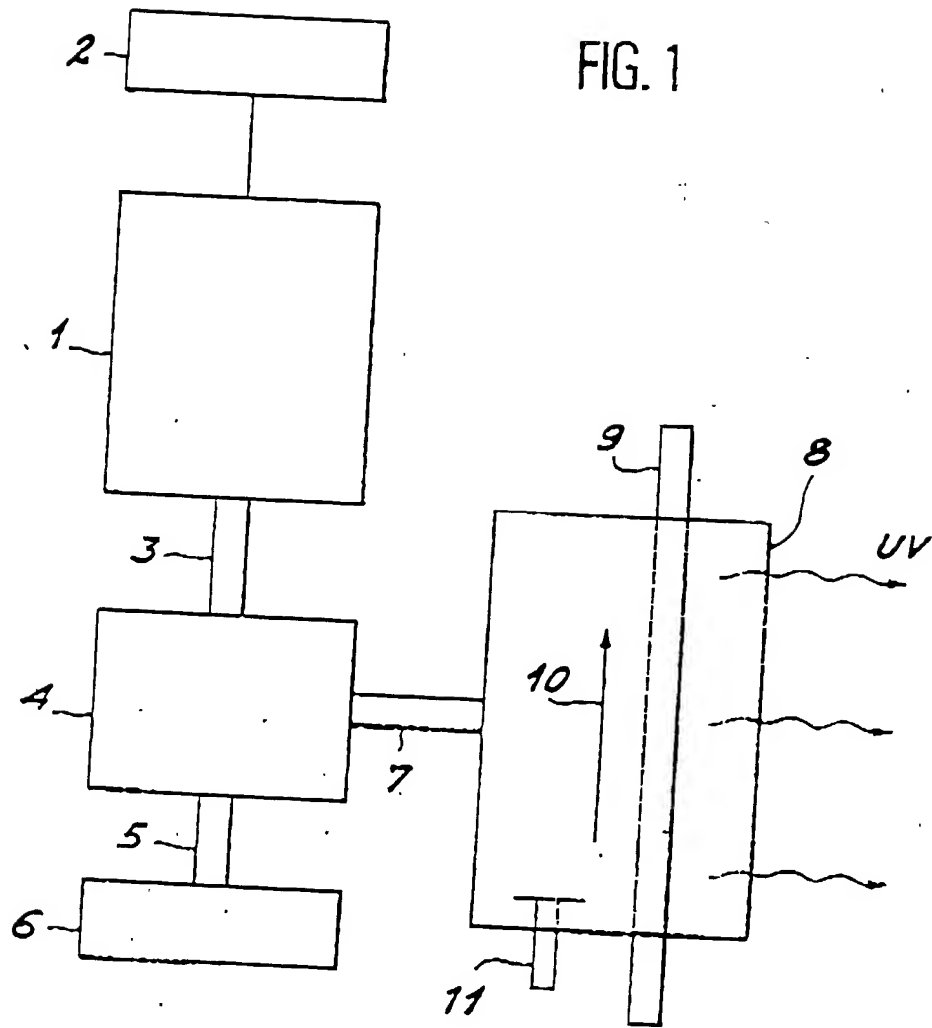


FIG. 2

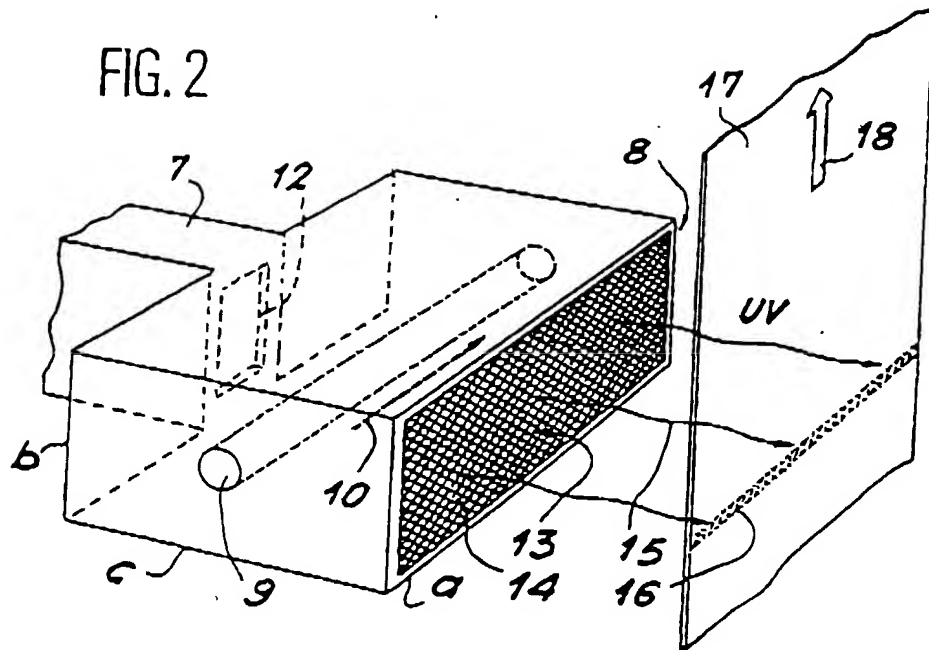
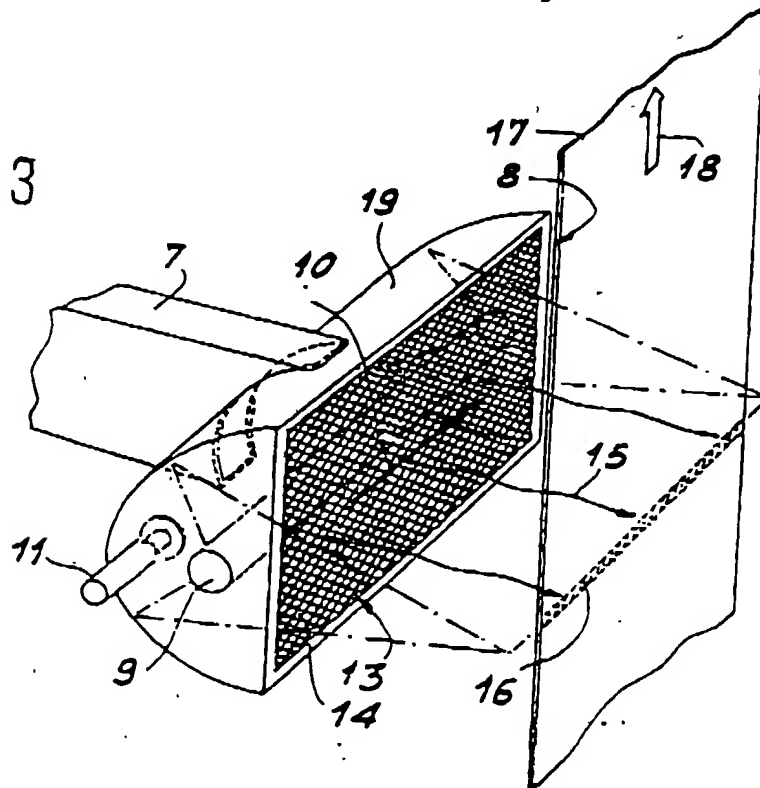


FIG. 3



Prior Foreign Application(s)

Priority Claimed?

<u>PCT/US00/25282</u>	<u>PCT</u>	<u>9/15/2000</u>	(✓) Yes ()
No	(Country)	Day/Month/Year Filed	
(Number)			
<u> </u>	<u> </u>	<u> </u>	() Yes ()
No	(Country)	Day/Month/Year Filed	
(Number)			
<u> </u>	<u> </u>	<u> </u>	() Yes ()
No	(Country)	Day/Month/Year Filed	
(Number)			

I hereby claim the benefit under Title 35, United States Code, §120 and/or §119(e) of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations §1.56, which became available between the filing date of the prior application and the national or PCT international filing date of this application.

<u>60/155,028</u>	<u>9/20/1999</u>	<u>Abandoned</u>
(Serial No.)	(Filing Date)	(Status: Patented, Pending, or
Abandoned)		
<u> </u>	<u> </u>	<u> </u>
(Serial No.)	(Filing Date)	(Status: Patented, Pending, or
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(Serial No.)	(Filing Date)	(Status: Patented, Pending, or
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David H. Brinkman
Wood, Herron & Evans, L.L.P.
2700 Carew Tower
441 Vine Street
Cincinnati, OH 45202-2917
Telephone (513) 241-2324

Wherefore I pray that Letters Patent be granted to me for the invention or discovery described and claimed in the foregoing specification and claims, and I hereby subscribe my name to the foregoing specification and claims, declaration, power of attorney, and this petition.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Full name of Inventor James W. Schmitkons

Inventor's Signature

James W. L. L. L.

Date

March 18, 2002

Residence City/State

Lorain, OhioOH.Citizenship USA

Post Office Address

43530 Middle Ridge Road, Lorain, Ohio 44053

2-00

Full name of Inventor James M. BorsukInventor's Signature James M. Borsuk Date 18 MAR 02Residence City/State Westlake, Ohio OH. Citizenship USAPost Office Address 30848 Lytham Circle, Westlake, Ohio 44145